INTEGRATION OF AMMONIA, UREA, AND NITRATES FOR SUSTAINABLE FERTILIZER PRODUCTION

STAMICARBON

NEXTCHEM
MAIRE Sustainable Technology Solutions

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Author(s)	Luca Amicucci
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1 ABSTRACT

This paper outlines a comprehensive integration strategy to produce ammonia, urea, diesel exhaust fluid (DEF), and calcium ammonium nitrate (CAN), aimed at driving the decarbonization of the fertilizer industry.

Through an in-depth analysis of three configurations—a DEF complex that harnesses CO_2 and steam integration, a CAN complex employing low-carbon ammonia and efficient nitric acid synthesis, and a small-scale urea facility with optimized purge and steam management—the paper highlights the significant advantages of interconnected plant operations.

Leveraging state-of-the-art technologies of Stamicarbon, the nitrogen technology licensor of NEXTCHEM (MAIRE Group), the approach brings together low-carbon energy sources, carbon capture and utilization (CCU), and advanced catalytic techniques within a single licensor framework.

2 INTRODUCTION

Fertilizer complexes are increasingly engineered as connected systems rather than standalone units. The motivation is clear: cross-unit integration—of process, waste, utilities streams—can shrink equipment counts and improve both environmental and economic performance. This paper presents a practical, Stamicarbon-wide integration approach within one licensor's framework to streamline interfaces, align guarantees, and de-risk commissioning and start-up. The focus is on how these integrations are structured and where they create value, rather than on restating technology fundamentals already covered elsewhere.

We examine three configurations that typify different deployment contexts:

- **Chapter 3– DEF complex:** A compact scheme where an NX CPO™ front-end provides hydrogen to the NX STAMI™ Ammonia loop and the captured CO_2 stream is routed to NX STAMI™ Urea; the chapter discusses layout, heat/steam interactions, and boundary conditions for DEF production.
- **Chapter 4– CAN complex:** A low-carbon route coupling the NH_3 loop to dual-pressure nitric acid and AN/CAN sections; the chapter details purge-to-burner routing, LLP-steam use in ammonium nitrate plant, and the role of O_2 integration from electrolysis/ nitrogen generation unit (NGU).
- **Chapter 5– Small-scale urea:** An integrated urea concept where the NH_3 purge is handled in the urea LP absorber, condensates are recycled as BFW, and the site steam balance is coordinated within the NH_3–urea envelope under a single-licensor execution model.

3 INNOVATIVE APPROACH TO DEF PRODUCTION

Diesel Exhaust Fluid (DEF) – also marketed as AdBlue – is a non-toxic, colorless aqueous solution containing 32.5wt% high-purity urea and 67.5wt% deionized water.

DEF is used in Selective Catalytic Reduction (SCR) systems on Diesel engines to abate harmful nitrogen oxide (NO_x) emissions. When DEF is injected into the hot exhaust stream, urea decomposes and hydrolyses to form ammonia (NH_3), which serves as the reductant over Cu-/Fe-zeolite SCR catalysts to convert NO_x to nitrogen (N_2) and water (H_2O), enabling compliance with modern emissions standards (e.g., Euro 6).

With the progressive tightening of emissions regulations worldwide, demand for DEF is rapidly increasing. In response, Stamicarbon has developed an advanced, integrated solution for DEF production.

Illustrated below (Figure 1) is a streamlined block flow diagram developed for a specific client in Canada, demonstrating a comprehensive process that transforms natural gas into DEF. This innovative scheme targets a production capacity of 615 MTPD of DEF 32.5, alongside 47 MTPD of aqua-ammonia solution (19 wt% NH_3).

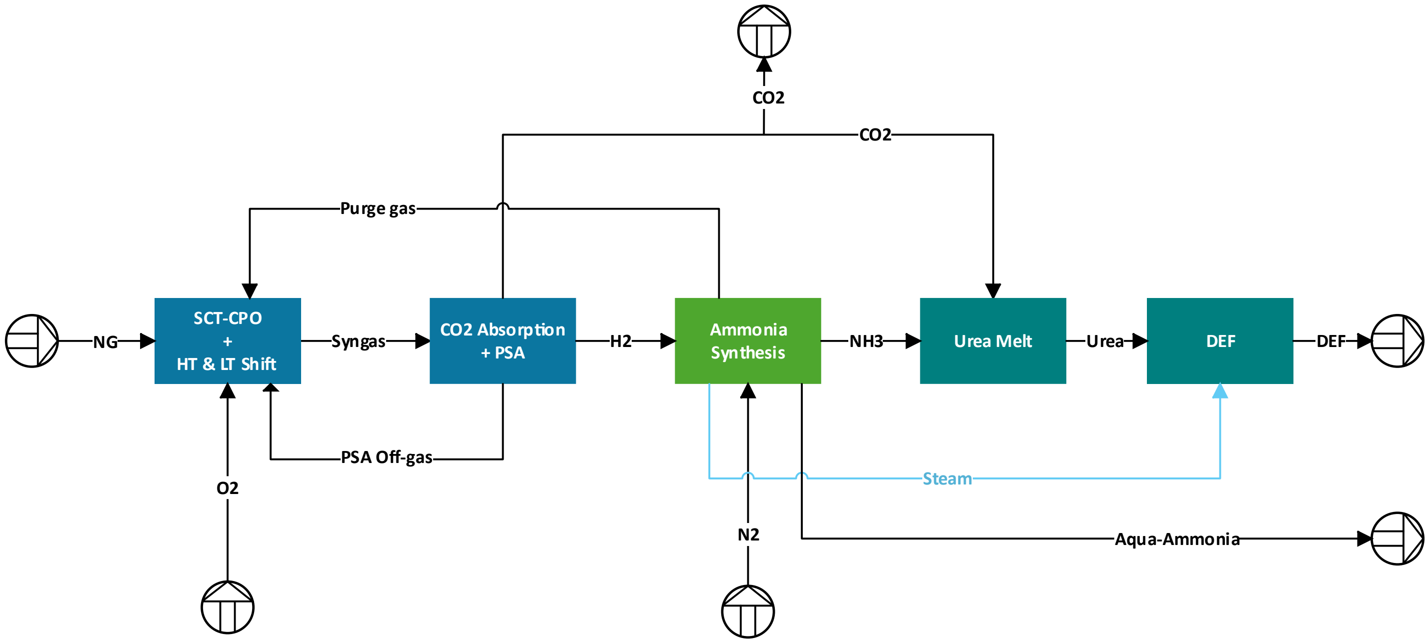

Figure 1: Overall block flow diagram of Hydrogen, Ammonia and Urea DEF integrated complex.

3.1 High-level process description – Hydrogen production unit

The hydrogen production unit (HPU) converts natural gas into high purity hydrogen required for the ammonia synthesis loop (Figure 2). The HPU utilizes a Short Contact Time-Catalytic Partial Oxidation (NX CPO™) reactor featuring a Rhodium-based catalytic bed which produces syngas via fast-reactions.

Natural gas serves as the main feedstock and is purified through hydrodesulphurization (HDS) to remove sulphur compounds before entering the SCT-CPO reactor. Concurrently, oxygen from the Air Separation Unit (ASU) and steam—generated by recovering heat from the SCT-CPO reactor's effluent—are blended with the purified natural gas. This mixture of natural gas, steam, and oxygen is then introduced into the SCT-CPO reactor, where several key reactions occur:

$$CH_4 + 2O_2 \leftrightarrow CO_2 + 2\,H_2O$$

$$CH_4 + \tfrac{1}{2}\,O_2 \leftrightarrow CO + 2H_2$$

$$CO + H_2O \leftrightarrow CO_2 + H_2$$

$$CH_4 + H_2O \leftrightarrow CO + 3H_2$$

Through these reactions, the feedstock is partially oxidized and reformed to produce synthesis gas (syngas), which is comprised of hydrogen, carbon monoxide, and carbon dioxide. The syngas is then 'shifted' using the Water Gas Shift (WGS) reaction—employing high-temperature shift (HT Shift) and low-temperature shift (LT Shift) reactors—to maximize hydrogen yield and reduce carbon monoxide content. Carbon dioxide is captured via an amine-based system (CO_2 absorption). To achieve high-purity hydrogen, the resulting gas stream undergoes purification through Pressure Swing Adsorption (PSA). During this process, the captured carbon dioxide (CO_2) is routed directly to the urea melt unit as feedstock. Since the CPO reactor generates more CO_2 than the urea plant requires, any surplus CO_2 is exported. The hydrogen is then supplied to the NX STAMI™ Ammonia plant.

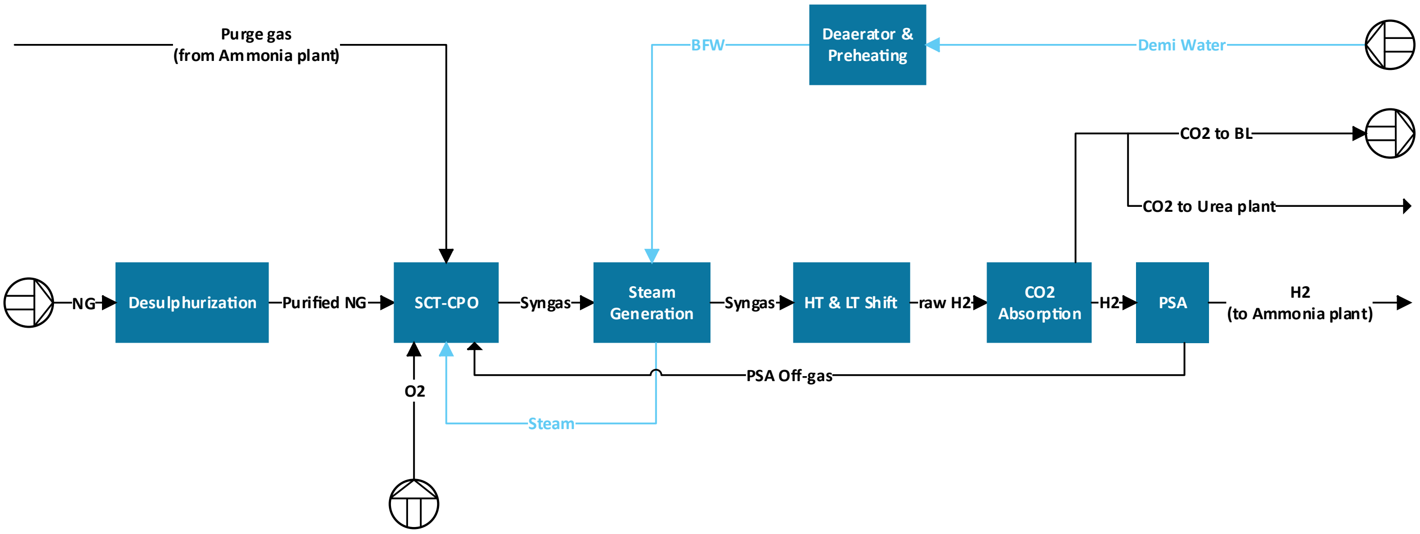

Figure 2: Block flow diagram of the HPU unit (NX CPO™).

The core component of the HPU is the advanced, proprietary NX CPO™ reactor. Its distinguishing features are outlined in Table 1, along with a comparison to conventional front-end technologies.

	NX CPO™	**Primary Reformer + Air-Fed Secondary Reformer**
Core equipment	Compact SCT-CPO reactor; no furnace/burners; no external fired feed-preheater; reuse of PSA off-gas recycle.	Large fired primary reformer (radiant + convection) + secondary reformer + process air compressor.
O_2 / ASU need	Requires high-purity O_2 from an ASU.	No ASU required; uses compressed process air to the secondary reformer.
Layout / footprint	Smaller plot (no fired reformer box) and only one reactor.	Largest footprint: fired primary reformer + secondary reformer + tall convection/stack + process air compressor.
Integration highlights	PSA off-gas recycle + purge gas from ammonia synthesis loop reduce NG use and support no-flare design. Syngas purification with amine-based CO_2 capture + PSA achieving extremely low level of impurities.	Process air compressor couples N_2 supply to ammonia synthesis; extensive heat recovery steam generation; classic ammonia integration. Syngas purification with amine-based CO_2 capture + methanation unit.

Table 1: Comparison between NX CPO™ and standard primary/secondary reformer configuration.

More details about the front-end NX CPO™ technology are available in the following paper/presentation: “Syngas production & carbon capture (Front-end ammonia)” by Cristina Guazzotti and Alexander Schulz

3.2 High-level process description – Ammonia synthesis loop

The ammonia production unit transforms hydrogen and nitrogen into liquid warm ammonia using the NX STAMI^{TM} Ammonia process, which employs high-pressure (HP) technology operating at 300-340 bar. This process is based on the Haber-Bosch synthesis reaction:

$$N_2 + 3H_2 \leftrightarrow 2NH_3$$

Hydrogen is supplied from the HPU and nitrogen from the ASU. Within the plant, these gases are mixed in the required molar ratio of 3:1 (hydrogen to nitrogen) to form the make-up gas. This stream is then blended with flash gas recycle stream from depressurization section before entering the electrically driven, multiservice reciprocating compressor.

Within this compressor, both the make-up gas and the recycle gas are pressurized to the required synthesis pressure. The same machine also handles the refrigerant fluid for the small refrigeration cycle, enabling partial condensation of ammonia coming from the recycle line and ensuring effective removal of any moisture to entry into the HP synthesis loop.

Following compression, the gas is directed to the HP axial-flow ammonia converter. The converter features a cold-wall, tube-cooled design and incorporates a built-in electrical heater. Within the reactor, the ammonia concentration rises from approximately 5% at the converter's inlet to between 22% and 26% at the outlet, depending on the start-of-run (SOR) and end-of-run (EOR) conditions.

The high-grade heat from the reactor effluent is utilized to generate HP steam required by the downstream DEF plant. After steam generation and preheating of the feed prior to entering the converter, most of the ammonia (>85%) is condensed using normal cooling water, taking advantage of the high dew point of the mixture at synthesis pressure. This allows to reduce the chiller load, employing a very small refrigeration loop upstream the ammonia converter.

The uncondensed gas mixture is recycled back to the compressor. To prevent the buildup of inert substances, a controlled purge stream is drawn off and sent to the HPU to be reused. Because this purge stream still contains ammonia, it first passes through a purge gas absorber, where most of the ammonia is captured and recovered.

The condensed liquid ammonia undergoes multiple flashing stages, reducing pressure from near-synthesis conditions to approximately 15 bar. These steps effectively strip out unconverted gases, which are then circulated back to the compressor suction as part of the flash gas recycle. The final liquid ammonia product is subsequently routed to the urea melt-DEF synthesis section. An aqueous-ammonia stream is also exported outside BL.

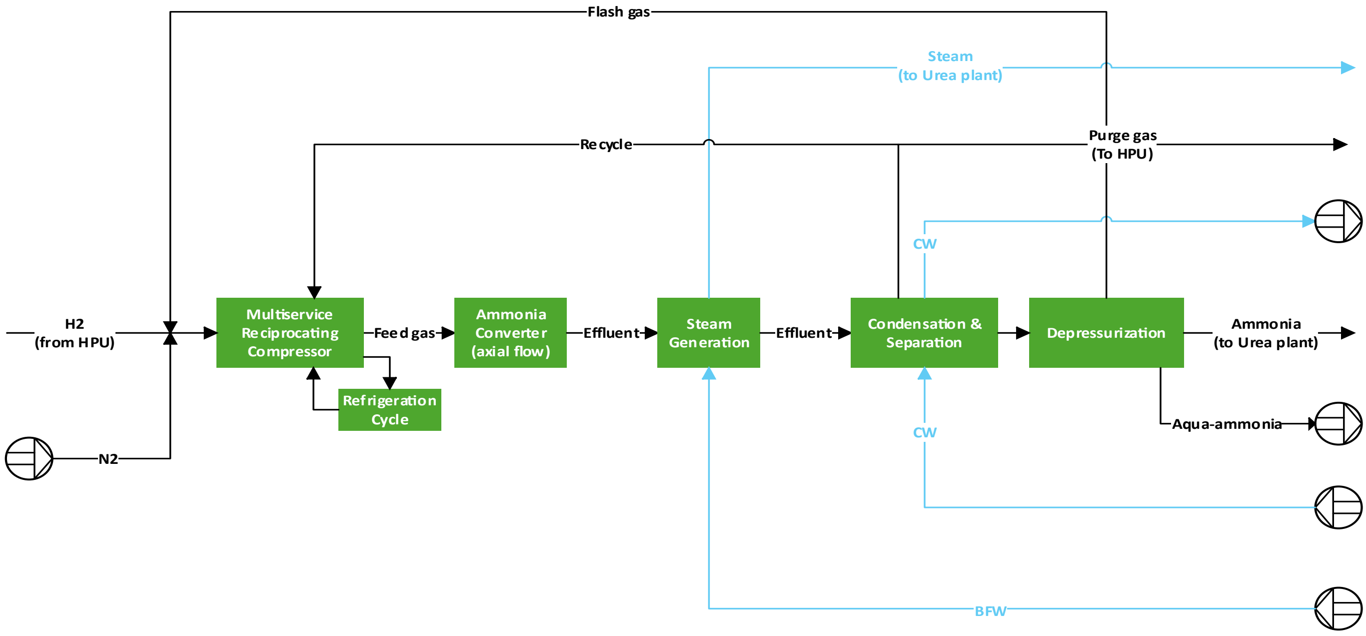

Figure 3: Block flow diagram of the NH_3 synthesis unit (NX STAMI^{TM} Ammonia).

Advantages of the NX STAMI^{TM} HP ammonia technology, alongside a comparison with a typical medium-pressure (MP) synthesis loop, can be found in Table 2 below.

	NX STAMI™ Ammonia High-Pressure synloop	**NX STAMI™ Ammonia Medium-Pressure synloop**
Operating pressure (loop)	~300–340 bar	~150–180 bar typical
Ammonia concentration at converter outlet	NH_3 downstream of converter ≈ 22-26 mol%	NH_3 downstream of converter ≈ 21 mol%
Compression concept	One multi-service reciprocating compressor (make-up + recycle + refrigeration), fully electric; high overall efficiency (~90%); no surge/choke limits	Separate centrifugal machines (syngas + refrigerant); refrigeration compressor typically steam-driven; anti-surge systems required
Refrigeration / condensation	> 85% of NH_3 condensed with cooling water → lower chiller load Two condensation steps, upstream (small refrigerant ammonia cycle) and downstream the ammonia converter (cooling water)	Multi-stage ammonia refrigeration down to ~−10 °C in effluent refrigerators; higher cold-duty machinery Single condensation step, downstream the converter
Converter design	Compact axial-flow ‘cold-wall’ design with integrated e-startup heater; very low catalyst inventory (3–4x lower vs. MP concepts at same capacity)	Multi-bed radial-flow with low Δp and optimized inter/intra-bed heat exchange
Equipment count / complexity	Lean plant (single compressor; compact exchanger train) → simple operability and sparing; highly modularized	More equipment items (multiple large compressors, larger cold section) and steam systems to integrate
Footprint & modularity	Small plot; high modularization → faster site works	Larger plot due to lower synthesis pressure.
CAPEX / deployment	Low CAPEX at small scale (lean design; fewer big machines); strong modularization benefits	OPEX & CAPEX optimized for larger capacities with integrated steam/power loops

Table 2: Comparison between NX STAMI^{TM} HP ammonia and typical ammonia (synthesis loop only).

More details about NX STAMI^{TM} Ammonia technologies can be found in the paper “Enabling Decentralized Ammonia Production with NX STAMI™ HP Synloop, Beyond the Base Case” – by Mahal Patel

3.3 High-level process description – Urea-DEF

The NX STAMI™ Urea urea-DEF unit transforms ammonia and carbon dioxide into urea melt, which is subsequently used to produce DEF. Urea synthesis begins with the reaction of liquid ammonia and gaseous carbon dioxide at about 170-185 °C and 134-145 bara according to following reaction:

$$2NH_3 + CO_2 \leftrightarrow NH_2COONH_4$$

$$NH_2COONH_4 \leftrightarrow CO(NH_2)_2 + H_2O$$

In the first reaction, carbon dioxide and ammonia are converted into ammonium carbamate. This reaction is fast and exothermic. In the second reaction, which is slow and endothermic, the ammonium carbamate dehydrates to produce urea and water. Carbon dioxide recovered from the HPU is compressed using a dedicated CO_2 compressor and directed to the stripper. The ammonia supplied from the ammonia plant is pressurized by an NH_3 pump and fed into the pool reactor. Within the pool reactor, the process is optimized by combining cooled and adiabatic zones.

The resulting reactor effluent, which contains urea along with unconverted reactants, is sent to the stripper. In this stage, carbon dioxide assists in the decomposition of residual carbamate. The reactor off-gasses are scrubbed in an MP scrubber with the recycled carbamate solution from the low-pressure (LP) recirculation section. The ammonia/carbamate solution from the MP scrubber is recycled to the synthesis. From the stripper the urea solution is sent to the LP recirculation section, where further decomposition and recovery of any remaining carbamate take place.

The urea solution is then treated in the pre-evaporation section to remove the remaining ammonia from the solution (while also evaporating water), to reach the ammonia specification for DEF. It is then mixed with demineralized water in a mixing vessel to reach the target 32.5% urea concentration for DEF. After dilution, the DEF solution is cooled and transferred to storage tanks, ready for distribution.

The final DEF product is a high-purity aqueous urea solution, specifically formulated to reduce NO_x emissions from diesel engines, supporting cleaner and more sustainable transportation.

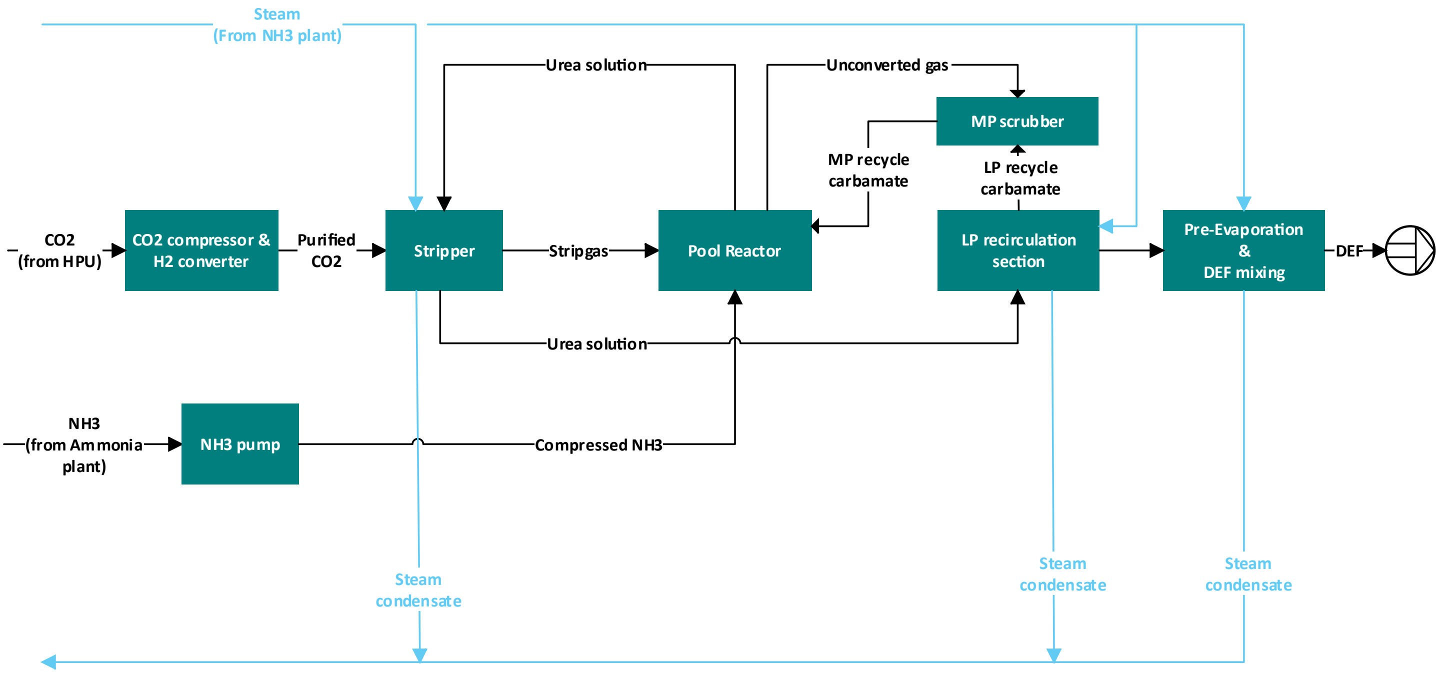

Figure 4: Block flow diagram of the urea-DEF unit (NX STAMI^{TM} Urea).

3.4 Key aspects/advantages

Key aspects of the plant configuration are highlighted below:

- **Minimized carbon footprint and efficient CO_2 supply for urea production:** The plant achieves a significantly lower carbon footprint by capturing CO_2 produced in the CPO unit. Unlike traditional front-end configurations that rely on primary and secondary reformers—where CO_2 generated from the combustion of natural gas (needed to provide heat to the endothermic SMR reactions) is released into the atmosphere—this design solely concentrates CO_2 in the CPO reactor effluent. As a result, emissions are greatly reduced, supporting sustainable operations. Furthermore, the urea plant's CO_2 requirement is more than adequate, without the need to oversize the front-end. All CO_2 generated in the CPO reactor—operating without a burner and thus avoiding combustion—is captured and utilized. In contrast, conventional setups typically recover only the CO_2 from the SMR reactor section, while CO_2 produced from natural gas combustion is often vented to the atmosphere. Excess of high-purity CO_2 is also exported to CO_2 pipeline without the need for additional treatment.
- **Integrated steam balance:** Steam generation and consumption are seamlessly coordinated across the hydrogen, ammonia, and urea production units. The HPU self-produces the steam necessary for SMR reactions (S/C ratio), while the ammonia plant supplies steam to meet the urea plant's requirements. This integrated approach optimizes energy use and enhances overall process efficiency.
- **Purge gas integration & low NG consumption:** The ammonia-free purge gas generated by the ammonia plant is efficiently repurposed as supplementary feedstock for the CPO reactor, decreasing feedstock consumption. Alongside the absence of any burner or external fired heater, the overall energy consumption of the complex is very low.

All these advanced features are provided under a single-licensor framework, ensuring seamless technology integration and streamlined project execution. The single point of contact represents a strong de-risking argument for lenders and banks.

4 DECARBONIZING FOOD VALUE CHAIN VIA SUSTAINABLE CAN PRODUCTION

Stamicarbon has developed an integrated concept targeting 500,000 TPA of CAN-27 at Languevoisin (France) within the FertigHy initiative, with NX STAMI™ high-pressure ammonia and dual-pressure nitric acid technologies at the core, interfaced with ammonium nitrate solution and CAN granulation technologies to deliver a single, coordinated site.

Commercialization is anchored by long-term offtake with leading agri-food players: the FertigHy consortium unites EIT InnoEnergy, RIC Energy, MAIRE, Siemens Financial Services, InVivo, and HEINEKEN, aligning low-carbon fertilizer supply with off takers' Scope-3 decarbonization goals. More than 50 % of the CAN volume has been already covered by preliminary offtake commitments (not binding), with the fertilizer primarily intended for use in agricultural applications, particularly for crop cultivation to support sustainable food production.

The fertilizer complex leverages reliable and stable low-carbon energy sources—primarily nuclear and wind power—to generate hydrogen through alkaline water electrolysis.

A simplified block flow diagram of the overall complex is shown in Figure below, which includes also process and utility integrations.

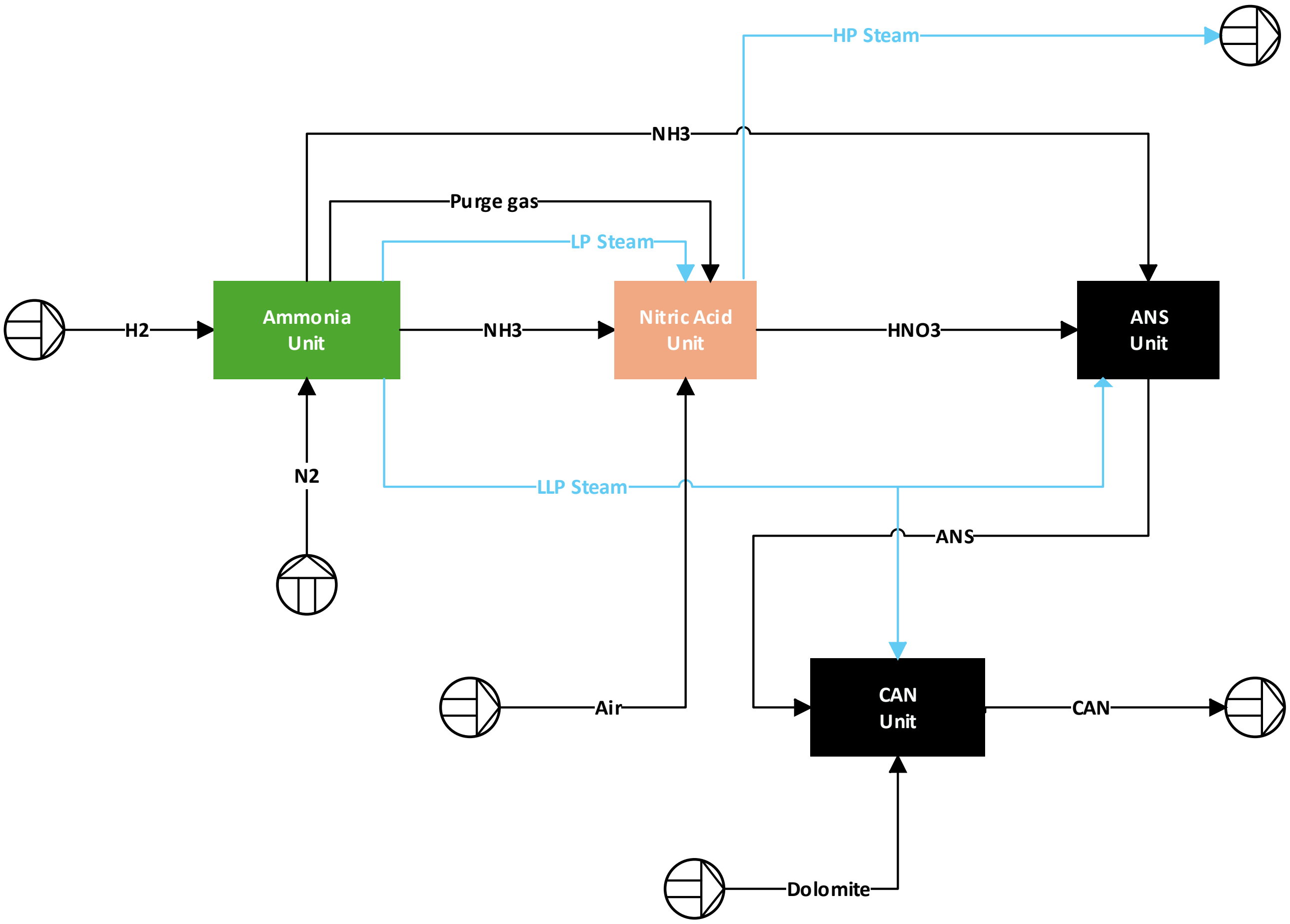

Figure 5: Block flow diagram of CAN fertilizer complex.

The ammonia process utilizes NX STAMI™ HP ammonia technology, as previously discussed in Section 3, using renewable hydrogen as a feedstock. For additional details, refer to the paper Enabling Decentralized Ammonia Production with NX STAMI™ HP Synloop, Beyond the Base Case – by Mahal Patel.

4.1 High-level process description – Nitric acid

The nitric acid process uses NX STAMI^{TM} Nitrates dual-pressure technology. Stamicarbon's dual-pressure nitric acid process splits the plant into an MP oxidation section and an HP absorption section to maximize heat recovery and minimize emissions, targeting the lowest total cost of ownership. The overall reactions happening in the plant can be summarized as follows:

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

$$2NO + O_2 \rightarrow 2NO_2$$

$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO$$

With also additional undesired side reactions like:

$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$$

$$4NH_3 + 4O_2 \rightarrow 2N_2O + 6H_2O$$

Air is filtered, preheated, and compressed to about 5 bar(a) (≈220 °C), while liquid ammonia delivered from NX STAMI™ Ammonia plant is evaporated with cooling water, then superheated and filtered. The streams are mixed in a static mixer and sent to a Pt/Rh-gauze burner operated at ~885 °C to oxidize NH_3 to NO with minimal Pt loss and limited formation of N_2 and N_2O. The strong exothermic reaction first generates HP steam and heats the tail gas to ~480 °C, after which the nitrous gas is cooled to ~160 °C in a gas/gas exchanger and partially condensed in an LP cooler-condenser to produce a weak-acid stream. The remaining gas is compressed to about 10–11 bar(a), cooled to ~115 °C with boiler feed water (BFW), and further cooled to ~50 °C in an HP cooler-condenser to form additional acid. In the tray-type oxidation/absorption column, NO oxidizes to NO_2 between trays while NO_2 is absorbed in water. Cooling coils remove the absorption heat, and the column bottoms are combined with condenser acid before final purification in a bleaching column that strips dissolved NO_x using secondary air (~10 % of total intake), which is then routed to the NO_x-compressor suction as an O_2 source.

Overhead gas (mainly N_2 with traces of NO_x, N_2O, and O_2) is reheated in stages back to ~480 °C and treated in a tertiary abatement reactor to reduce NO_x and N_2O to < 20 ppmv, then expanded to recover power for the air and NO_x compressors (with steam-turbine assist) before a final cooler drops the stack temperature to ~110 °C. The configuration is proven from ~600 to 2,000 TPD per train.

Advantages of the NX STAMI™ Nitrates dual-pressure nitric acid technology, alongside a comparison with a conventional one, can be found in Table 3 below.

	NX STAMI™ Nitrates Dual-pressure nitric acid technology	Conventional nitric acid technology (typical)
Tail-gas heat integration & expander inlet temperature	Third tail-gas heater located in the burner vessel (below superheater, before boiler) raises expander inlet to ≈480 °C (≈50 °C above conventional).	Typical layouts without the extra heater achieve ≈430 °C expander inlet.
HP steam export capability	> 800 kg steam/t HNO_3 exported, typically at ~45 bar(a), 450 °C (pinch-optimized HX layout)	~ 600 kg steam/t HNO_3
Emissions after tertiary abatement	NO_x and N_2O < 20 ppmv are achievable thanks to favourable tail-gas temperature at the tertiary catalyst.	Low emissions are also achievable with tertiary abatement; guarantees and catalyst systems vary by licensor.

Table 3: Comparison between NX STAMI™ Nitrates nitric acid technology and conventional technology.

The CAN section, provided by another licensor, is designed to deliver high-quality fertilizer granules with excellent physical and chemical stability.

Stamicarbon’s expertise in plant integration plays a pivotal role in maximizing the efficiency and sustainability of the entire complex. This is evident in the synergy between its ammonia and nitric acid technologies. The integration strategy is designed to reduce emissions, optimize resource use, and lower both capital and operational expenditures.

4.2 Key aspects/advantages

The key advantages brought by this plant configuration can be summarized as follows:

- **Purge gas integration:** By routing purge gas directly from the ammonia plant to the nitric acid plant (ammonia burner), Stamicarbon eliminates the need for a dedicated purge gas absorber and the associated chilled cooling water (CCW) system, including all pumps and heat exchangers required for removing the heat generated by water/ammonia mixing. This approach ensures that no continuous emissions are present within the ammonia plant. Moreover, it significantly reduces both investment and operational costs.
- **Steam integration:** The integration of LP steam (8 bara, saturated) within the nitric acid plant maximizes the steam export of the nitric acid plant. By utilizing the LP steam produced by the ammonia synthesis loop, the high-quality steam produced by the HNO_3 plant, which has to be let

down for internal consumption and consumer downstream, can be reduced. This integration not only enhances efficiency but also contributes to overall cost savings. Part of the LP steam produced within the ammonia synthesis loop is let down to 6 bar (LLP steam) and also used within the ammonium nitrate solution and granulation plants, eliminating the need for steam import from outside the battery limit with a consequent lower operational cost. The produced steam is sufficient for normal plant operation. This comprehensive integration underscores Stamicarbon's commitment to delivering innovative and sustainable solutions for its clients.

- **Oxygen integration:** For green ammonia production, hydrogen and nitrogen are typically obtained from electrolyzers and NGU respectively. One of the side products from both processes is O_2, with 1.6 ton O_2 produced per ton of NH_3 needed. This can be utilized in several ways in the nitric acid plant to improve the performance of the plant and reduce total emissions of NO_x and N_2O. In this case, oxygen is received at higher pressure than the nitric acid process and it is injected directly into the bleaching column. The addition of oxygen will fully or partially replace the secondary air typically used as a stripping agent. As a result, the top gas outlet from the bleaching column becomes oxygen-rich, which is then redirected back into the process, where higher O_2 concentration enhances the oxidation of NO to NO_2. This improvement leads to higher oxidation efficiency in the cooler/condensers and the oxidation/absorption column. Besides, the load of the air compressor will be reduced and if plant capacity is maintained, the reduction in power consumption by the air compressor will be translated into higher steam export. More details about oxygen integration and utilization within the nitric acid plant can be found in the following paper: “Next-generation nitric acid production: Total recycle and alternative concepts” by Paz Muñoz.

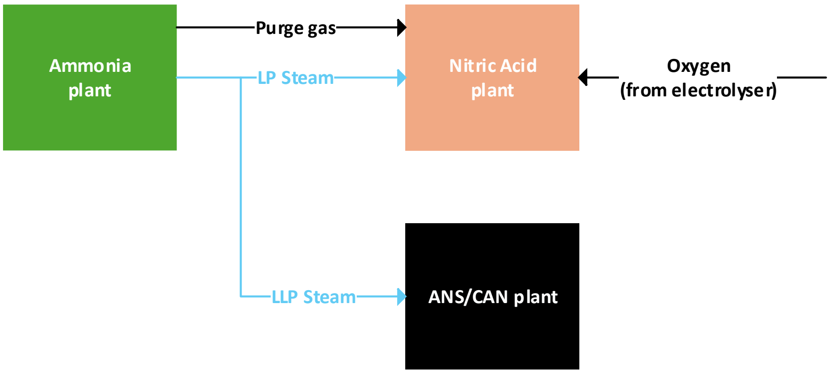

Figure 5: Simplified block scheme of the integrations.

This comprehensive integration of the above-mentioned technologies underscores a shared commitment to delivering innovative, efficient, and environmentally responsible solutions. It sets a new benchmark for low-carbon fertilizer production, combining technical excellence with a forward-looking approach to industrial sustainability.

5 IDENTIFYING SYNERGIES IN SMALL-SCALE UREA PLANT

The concept presented is driven by the growing demand for small-scale urea plants utilizing green ammonia technology. It enables sustainable, localized fertilizer production by sourcing CO_2 flexibly - from flue gas, existing CO_2 grids, nearby capture facilities, or CO_2 pipelines.

To address this need, Stamicarbon has developed a fully integrated solution encompassing both process and utility, which merges ammonia production (NX STAMI™ Ammonia), urea melt synthesis, and granulation finishing technologies (NX STAMI™ Urea) within a single licensing framework. The design is optimized for producing 100 MTPD of urea granules, though the system’s versatility allows for various finishing options, including prills, DEF, or UAN, depending on client needs.

In Figure 8 below the overall block flow diagram of the combined plant is represented.

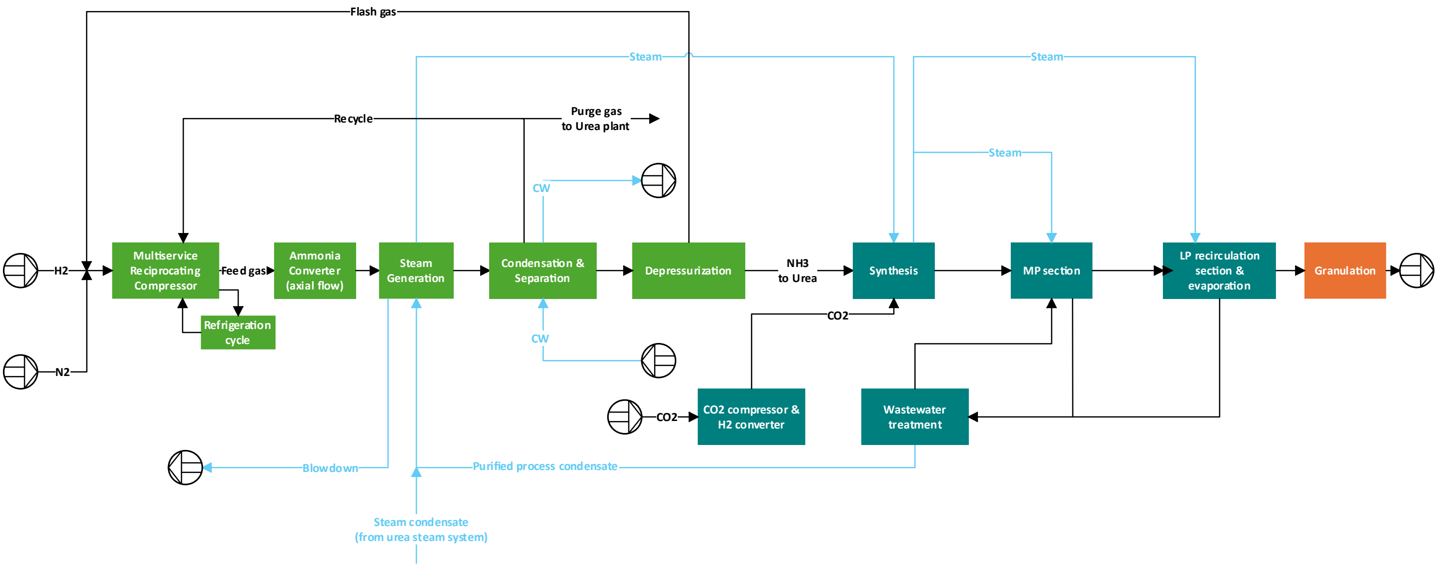

Figure 6. Overall block flow diagram of the combined ammonia-urea plant.

The ammonia process utilizes NX STAMI™ HP ammonia technology, as previously discussed in Section 3, using renewable hydrogen as a feedstock. For additional details, refer to the paper "Enabling Decentralized Ammonia Production with NX STAMI™ HP Synloop, Beyond the Base Case – by Mahal Patel

5.1 High-level process description – Urea melt & granulation

The urea process utilizes the NX STAMI™ Urea Adiabatic Flash 2.0 technology, while the granulation plant is based on the standard granulation technology with solids flow type final product cooler.

The concept employs Adiabatic Flash 2.0 technology to maximize process integration and minimize steam consumption, aiming for the ammonia plant to supply all required steam and thus lower operational costs. Unlike the concept presented in Section 3, this technology features a complete melt and finishing section specifically designed for granulation, producing a high-purity urea melt at 98.5 wt%. This higher concentration necessitates a multistage evaporation system and a process condensate purification unit to ensure the final purified process condensate contains minimal ammonia and urea residues. For more details on this technology reference is made to paper 'NX STAMI™ Urea Adiabatic Flash Design 2.0'.

The granulation plant utilizes a fluidized bed process to produce high-quality granular urea. In the granulator, concentrated urea melt is sprayed in a thin layer onto recycled seed particles, which are kept suspended and fluidized by fluidization air. Granule growth is achieved by the progressive solidification of successive layers of urea melt onto the seed particles, resulting in uniform particle size and consistent granule shape. To enhance granule strength and minimize dust and caking during handling and storage, a small amount of urea formaldehyde is added to the melt as a process aid.

The granulator is divided into two main zones: the granulation zone and the cooling zone. In the granulation zone, seed particles are exposed to the urea melt spray and gradually increase in size as they move through the bed. Fluidization air ensures separation between particles, preventing agglomeration and supporting controlled growth. The downstream cooling zone then cools and hardens the granules, preparing them for subsequent handling and storage.

After granulation and cooling, the product is conveyed to the screening section, where any lumps are removed and sent to a dissolving system. The screened material is elevated to a classification unit, which separates it into on-size, coarse, and fine fractions. The on-size product is directed to a product cooler, where it is cooled to storage temperature under controlled humidity conditions before being transferred to storage through a weighing system.

The coarse fraction is crushed, and the crushed material is recycled together with the fine fraction back into the granulator as seed material. This recycling loop is crucial for stable plant operation and consistent product quality.

Air from the granulator, product cooling, and de-dusting systems carries entrained urea dust, which is treated in a wet scrubber. The scrubber dissolves the dust in a circulating urea solution, which is sent to the dissolving system. Cleaned air is released to the atmosphere, and the recovered urea solution is returned from the dissolving vessel to the urea melt plant, ensuring full process recovery and minimizing waste.

5.2 Key aspects/advantages

A defining feature of the integrated ammonia-urea concept is its high level of process and utility integration, which enhances efficiency and reduces both capital and operational expenditures.

- **Process integration:** A standout innovation in the integrated plant design is the optimized handling of purge gas from the ammonia unit. Conventionally, this hydrogen and ammonia-rich purge stream would require a dedicated absorber tower within the ammonia plant, along with associated equipment such as heat exchangers and pumps, to recover ammonia and maximize production. In the new approach, however, the purge gas is redirected to the LP absorber in the urea plant. This strategy eliminates the need for separate purge gas absorption equipment, streamlining the ammonia plant’s layout and reducing the system’s overall footprint. Additionally, it offers the benefit of minimizing continuous emissions from the ammonia synthesis loop, further supporting environmental sustainability and operational simplicity.
- **Steam and utility integration:** Another key integration point is the reuse of condensate streams and self-sufficient steam integration. Purified process and steam condensates produced within the urea plant are recovered (prior additional treatment, if necessary) and reused as BFW in the ammonia section for steam production. More than 87% of the steam demand is met by the ammonia unit, with the remaining demand covered by a small auxiliary electrical boiler. This closed-loop approach lowers freshwater requirements and enhances thermal efficiency, with a unified blowdown system for the entire plant. As a result, clients benefit from a highly sustainable operation that eliminates the need for imported steam or fuel-fired boilers, reducing both operational costs and environmental impact.

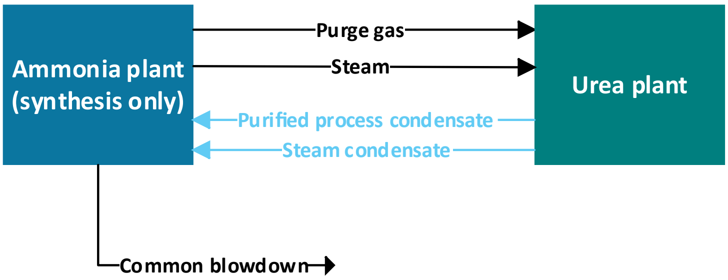

Figure 7: Schematic of the integration.

The proposed scheme is primarily designed around green ammonia technology, ensuring optimal integration with sustainable hydrogen sources. Nevertheless, it can be adapted to accommodate a variety of front-end technologies, such as the NX CPO™. This alternative technology is particularly well-suited for the plant’s scale and aligns seamlessly with the specific CO_2 requirements of the urea production unit. By allowing for multiple front-end options, the scheme supports both technological versatility and the evolving needs of clients focused on efficient, low-carbon fertilizer manufacturing.

6 CONCLUSION & TAKEAWAYS

The integrated fertilizer concepts presented in this paper offer clients a compelling pathway toward sustainable and efficient fertilizer production. By leveraging a single licensor for hydrogen generation unit, ammonia, urea melt, and finishing, the approach ensures a streamlined design, cohesive performance guarantees, and consistent operating philosophy from the outset. This not only accelerates project execution but also reduces handover complexity and overall project risk, resulting in a smoother commissioning and start-up process.

A key advantage for clients is the technological versatility embedded in the scheme. Whether utilizing green ammonia technology or alternative front-end options like NX CPO™, the system adapts to diverse production needs and evolving market demands, particularly for those seeking efficient, low-carbon solutions. Furthermore, the focus on small-scale applications empowers decentralized fertilizer production, allowing facilities to operate independently from large-scale infrastructure and respond effectively to local agricultural needs.

Process and utility integration further maximize operational efficiency by minimizing energy and resource consumption. Innovations such as direct routing of purge gas, condensate reuse, and integrated steam management contribute to reduced equipment requirements and enhanced sustainability. These features not only lower operating costs but also support clients' decarbonization goals by reducing the plant's carbon footprint.

The ability of Stamicarbon and its sister companies within NEXTCHEM (MAIRE Group) to deliver a fully integrated solution—from front-end hydrogen production to ammonia synthesis and downstream urea processing—provides clients with a single point of expertise and comprehensive support. This positions them as leaders in innovative fertilizer technology, offering clients robust, future-ready solutions that align with global trends toward renewable feedstocks and local production.

In summary, clients benefit from faster project delivery, reduced risk, lower energy usage, and greater adaptability to changing market and environmental requirements. The integrated approach drives both economic and environmental value, supporting clients as they transition to sustainable manufacturing.

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Stamicarbon B.V.

REGISTERED OFFICE
Mercator 3, 6135 KW Sittard,
The Netherlands
P.O. Box 53 - 6160 AB Geleen
P +31 46 4237000
F +31 46 4237001

l.amicucci@nextchem.com
Process Engineer

stamicarbon.com

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NEXTCHEM Sustainable Technology Solutions

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